Logic and probabilities for recommender systems

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Contents

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- Input and output
- Which probabilities we need?
- Simple layered semantics
- Cumulating evidence
- Rankings via meta-logical calculations

Recommender systems?

- Several historical „expert systems“ were recommender systems (medicine etc)
- Google is a popularity-focused recommender
- Social network systems are recommender systems: recommend news items and possible friends and topics
- The wealth of data available online makes it possible to create recommenders for any kinds of tasks and goals

Two main recommender types

- Collaborative filtering
- Rule-based, also called content-based

Our tourism recommender project

- http://www.sightsplanner.com
- http://www.sightsmap.com

Firefox

Sightsplanner

http://tallinn.sightsplanner.com/

android 2.2 start without butt

VISITOR | PROFESSIONALS | MEETING PLANNER | TALLINN.EE | TALLINN.MOBI

EESTI | ENGLISH 27.03.2011 | 12:57

Tallinn

Sightsplanner

The best guide to town

Walk in the city

Nice walk around the medieval Old town, history and cafes

Choose

Active life

Great events, spiced with sports and outdoor activities

Choose

A night in the town

Clubs, pubs, party and dancing all night long!

Choose

Culture

Beautiful architecture, amazing paintings and concerts

Choose

Get your plan

or see what's popular

Less More

- Events
- Museums & Arts
- Architecture & City
- Eating out
- Shopping
- Sports & Outdoor
- Bars & Nightlife

Time 14:00 28.03.2011 Duration 1h 2h 3h 6h 8h by car on foot

Firefox

Sightsplanner

http://tallinn.sightsplanner.com/

android 2.2 start without butt

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Less More

+ Events

- Museums & Arts

Modern art gallery
Installation, Happening
Old history museum
Science museum

Classical art exhibition
Other art
Contemporary history
Nature museum

+ Architecture & City

- Eating out

Traditional restaurant
European restaurant
Fine dining

Asian restaurant
Other restaurant
Pub

Time 14:00 29.03.2011 Duration 1h 2h 3h 6h 8h by car on foot

1. Estonian History Museum - Great Guild Hall Read more Locate on map

Museums and Arts Architecture and City Old history museum Medieval architecture

In the course of time, the Great Guild Hall has played an important role in the life of the city. The permanent exhibition of the History Museum located in the building introduces Estonia's history...

Arrive 14:05
Stay
45
minutes
Remove from selection

Walk 5 minutes

2. Katariina käik (St Catherine's Passage) Read more Locate on map

Landmark Architecture and City Medieval architecture

Vene and Müürivahe Streets are connected by Katariina käik. You can see the remaining parts of St Catherine's Church in its northern end The southern part of the passage is lined by residenti...

Arrive 14:55
Stay
20
minutes
Remove from selection

Walk 5 minutes

3. Olde Hansa Read more Locate on map

Eating out Traditional restaurant

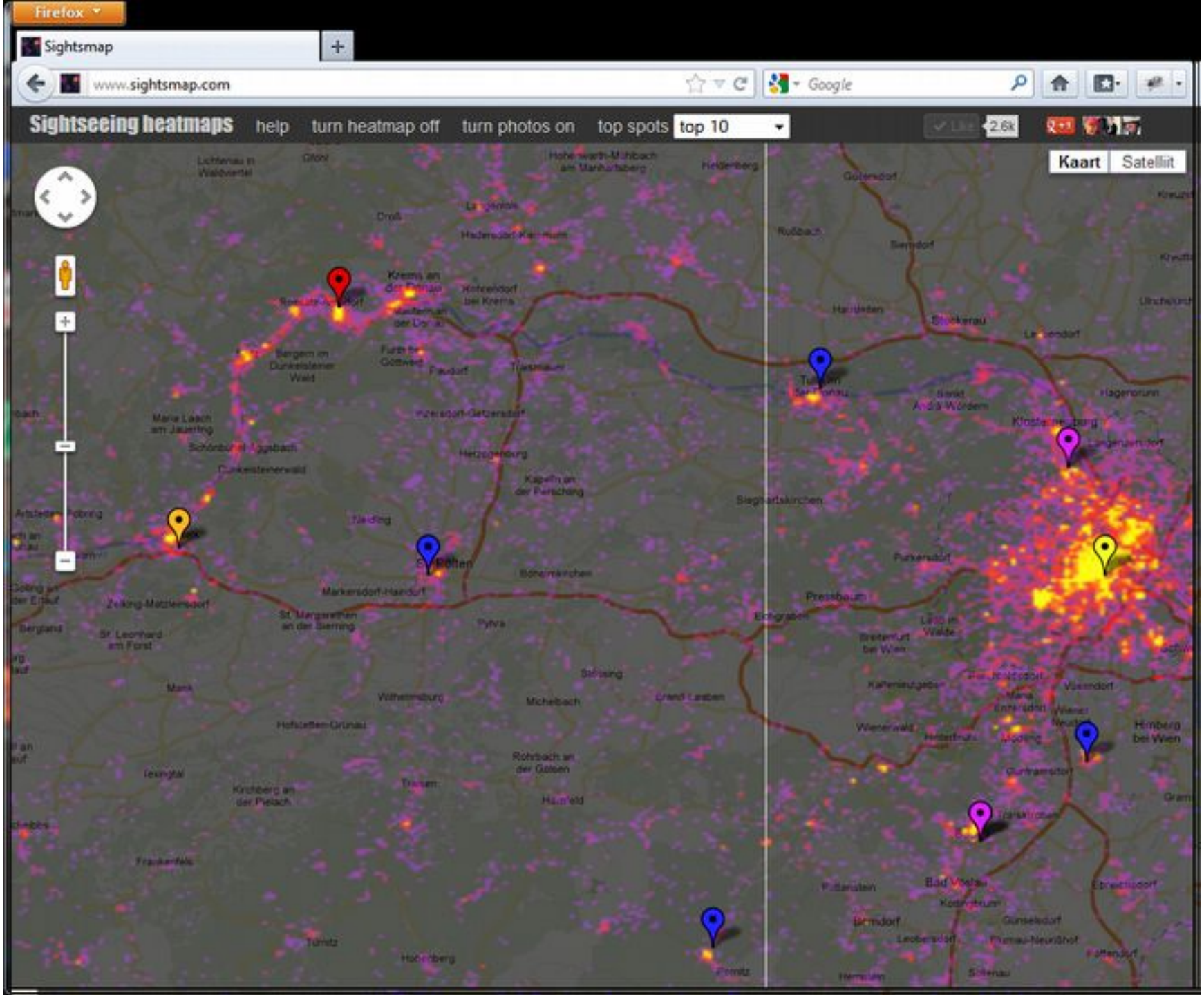
Olde Hansa Restaurant

See more

Arrive 15:20
Stay
60
minutes
Remove from selection

Walk 10 minutes


Firefox
Sightsplanner
http://tallinn
Tallinn
Sightsplanner
Suggest more
1. Katarina käik (St Catherines Passage)
2. Kärts
3. Masters Yard
4. Town Hall Square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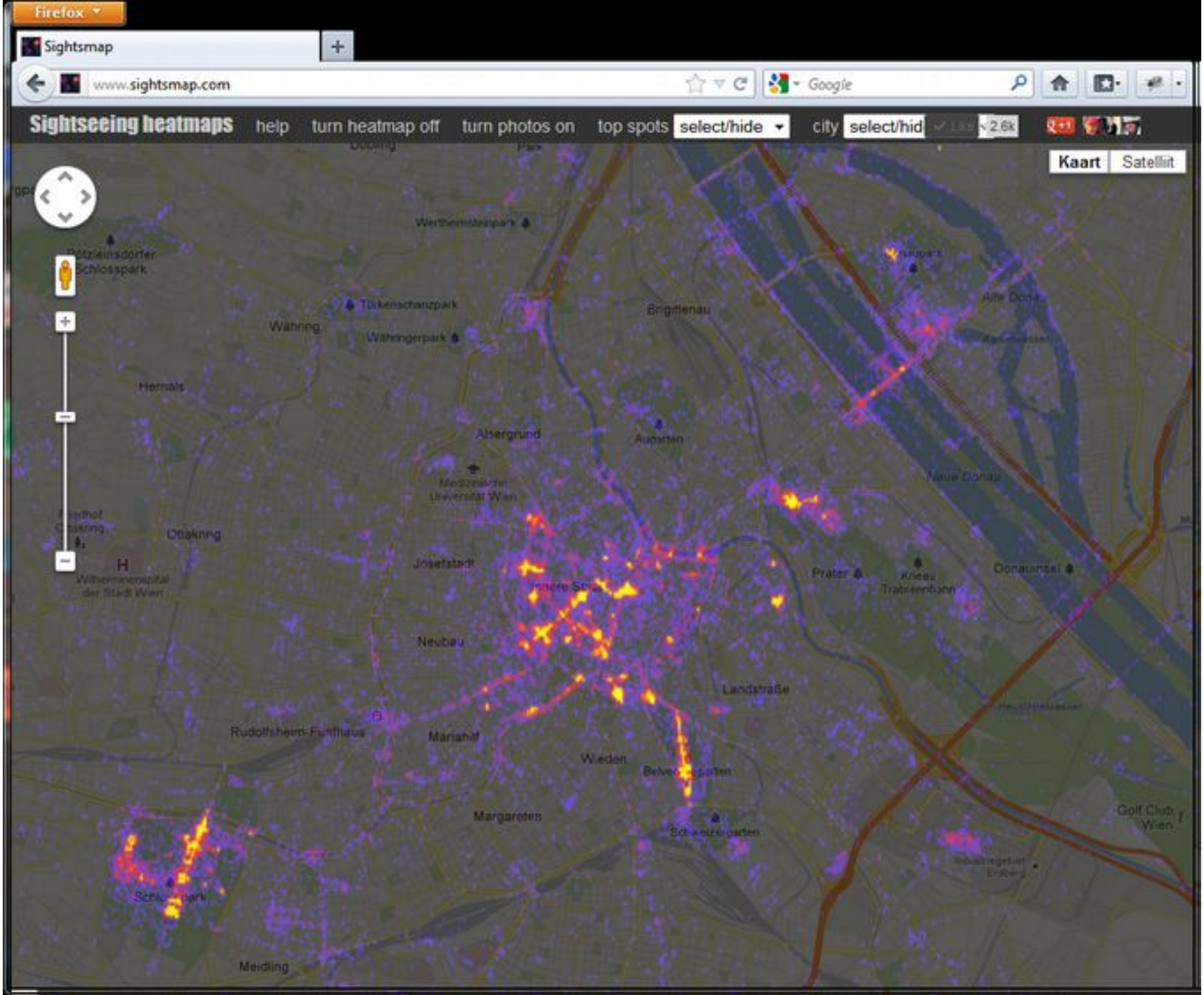
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www.sightsmap.com
Google
Sightseeing heatmaps
help
turn heatmap off
turn photos on
top spots
select/hide
city
select/hid
Kaart
Satelliet
Währing
Hernals
Alsergrund
Josefstadt
Ottakring
Neubau
Landstraße
Wieden
Margareten
Meidling
Brigittenau
Prater
Donauinsel
Rudolfsheim-Fünfhaus

Input 1

- User interests:

likes(john,nightlife,0.6)

likes(john,sports,0.8)

likes(john,music,0.7)

likes(john,heavymetal,0.9)

dislikes(john,classicalmusic,0.9)

Input 2

- Object properties:

type(omalley,bar,0.9)
activity(omalley,footballwatching,0.7)
popularity(omalley,1000)

type(crown,restaurant,1.0)
activity(crown,heavymetal,0.8)
popularity(crown,1500)
opentime(crown,12.00,0.9)

Input 3

- Knowledge about the world:

type(X,church,M) -> type(X,architecture,M*0.9)
type(X,bar,M) -> type(X,drinkingplace,M)
type(X,restaurant,M) -> type(X,drinkingplace,M*0.7)
activity(X,footballwatching,M) -> activity(X,sports,M)

type(X,fastfood,M) -> visitminutes(X,20,0.8*M)
type(X,bar,M) & M>0.75 -> openat12(X,0.85)

description(X,S) & contains_str(S ,“paintings“) & contains_str(S ,“gallery“)

->

type(X,artcollection,0.8)

Output

- Recommendations: numerical ranks for all tourism objects:

rank(john,omalley,0.6)

rank(john,crown,0.5)

Reasoning tasks

- Object identities: are two objects A and B obtained from different sources actually equal?
- Object types from content: using title, abstract, source etc, calculate wheather the object is a city, a castle, a church, medieval, modern, a drama play, a classical music concert, a rock concert, ...
- Generalised object types: if we know that an object is a bar (with some confidence X), then it is also a nightlife spot (with some confidence Y)
- Additional properties like time of visit, opening times
- How well does an object match user preferences

Probabilities?

There is a large number of probability-oriented theories and several reasoning systems, yet no "mainstream" probabilistic rule-based derivation algorithms exist

Fuzzy logic, probabilistic logic, Bayes networks, ...

Probabilistic datalog, probabilistic prolog, ...

Mycin, Emycin, Cadiag-2, ...

Goal

Formulate a practical, correct and complete way to use probabilities in rules for the (tourism) recommender context, using object logic.

Metalogic:
0.9: type(X,church) -> type(X,architecture)
0.8: type(X,fastfood) -> visitminutes(X,20)

Object logic:
type(X,church,M) -> type(X,architecture,M*0.9)
type(X,fastfood,M) -> visitminutes(X,20,M*0.8)

Which kinds of probabilities?

Non-strict sets a la „blue“, „large“, ...

Fuzzy logic : p(A v B) = max(p(A),p(B))

0.95: type(X,church) -> type(X,architecture)

0.7: type(X,theatre) -> type(X,architecture)

Incomplete knowledge a la „not sure that“ ...

Probabilistic: p(A v B) = p(A)+p(B) – (p(A)*p(B))

0.8: type(X,bar) -> openat12(X)

Object logic:

type(X,church,M) -> type(X,architecture,M*0.9)

type(X,fastfood,M) -> visitminutes(X,20,M*0.9)

Object logic layers of interpretation

Pred(t): Pred(t) holds.
Pred(t,m): Pred(t) holds with a fuzzy measure at least m.
Pred(t,m,c): With confidence (probability) at least c, Pred(t) holds with at least a fuzzy measure m.
Pred(t,m,c,d): The fact "with confidence (probability) at least c, Pred(t) holds with at least a fuzzy measure m,, holds and depends on the set of clauses d.

Examples

bar(malloy,0.9,1): we are certain that malloy is bar with a fuzzy measure at least 0.9

bar(crown,0.9,0.8): we are 0.8 confident that crown is a bar with a fuzzy measure at least 0.9

Rule examples

bar(X,M,C) & M>L -> openat12(X,1,C*0.8):

when we have confidence C in that X is a bar with a measure M at least L, we are C*0.8 confident that it is open at 12 with a measure 1.

optionally
bar(X,M,C) -> openat12(X,1,M*C*0.8):

example of a sure rule:

bar(X,M,C) -> can_eat_at(X,M*0.5,C):

Fuzzy part is easy

Use your own preferred function f and limits for fuzzy derivation

Pred(X,M1) & Pred(X,M2) -> Pred(X, f(M1,M2))

Pred(X,M) & M>L -> Pred(X, f(M))

Standard derivation rules in resolution hold, nothing is added.

We can enhace subsumption, provided f is monotonic:

Pred(X,M1) subsumes Pred(Y,M2) iff Y=Xs and M1>=M2.

Probabilistic part requires tracking

Recall P(t,M,C,D): C is the probability and D is the set of facts on which the atom depends upon.

Always use rules of form

P(....,D1) & ... & P(...,Dn) & A1 & .... & An ->
P(....,union(D1,...,Dn))

where P atoms do contain probabilities and
A1 ... An do not contain probabilities

Multiplying probabilities

Generally the rules should have a form

P1(t1,M1,C1,D1) & ... & Pn(tn,Mn,Cn,Dn) ->
P(t,M,f(M1,...,M2),g(C1,...,Cn,D1,...,Dn),union(D1,...,Dn))

- In simple cases g(C1,...,Cn,D1,...,Dn) = C1*...*Cn
- However, if intersection(D1,....,Dn) is not empty, Ci-s corresponding to Di-s with multiple occurrences should be used only once

Cumulating evidence

Use evidence cumulating rule schema:

Pred(X,M1,C1,D1) & Pred(X,M2,C2,D2) &
Empty(Intersection(D1,D2))
->
Pred(X,min(M1,M2),(C1+C2)-(C1*C2),union(D1,D2))

Cumulating evidence

Example: independent facts

a) bar(X,M,C,D) & M>0.75 -> openat12(X,1,C*0.8,D)
b) intitle(X,"allnight",M,C,D) & M>0.75 -> openat12(X,1,C*0.9,D)
c) bar(malloy,1,1,{c}).
d) intitle(malloy,"allnight",1,1,{d}).

a,c: e) openat12(malloy,1,0.8,{c})
b,d: f) openat12(malloy,1,0.9,{d})

giving for our case (0.8+0.9=1.7, 0.8*0.9=0.72, 1.7-0.72=0.98)
openat12(malloy,1,0.98,{c,d})

Cumulating evidence

Example: dependent facts

f) activity(X,heavymetal,1,1,D) -> activity(X,music,1,1,D).

g) activity(X,Y,M1,C1,D1) & likes(U,Y,M2,C2,D2) ->
fits(U,X,1,M1*M2*C1*C2,union(D1,D2))

a) likes(john,music,1,0.6,{a})

b) likes(john,heavymetal,1,0.8,{b})

c) activity(crown,heavymetal,1,1,{c}).

c,f: h) activity(crown,music,1,1,{e}).

g,a,h(cf): i) fits(john,crown,1,0.6,{a,c})

g,b,c: j) fits(john,crown,1,0.8,{b,c})

Cumulating prohibited, since i and j share c

Ranking calculation in meta-logic

- Derive all open-at-time facts.
- Derive all independent addrank facts, using:

Popularity(X,P) -> addrank(X,pf(P))

Likes(X,Y,M1) & assoc(Z,Y,M2,C,D) ->
    addrank(X,Z,f(M1,M2,C),D)
Dislikes(X,Y,M1) & assoc(Z,Y,M2,C,D) ->
    addrank(X,Z,nf(M1,M2,C),D)

- Sum all maximal pos/neg addrank numbers for objects.
- Filter out objects which are open at time.
- Order by rank.

Summary 1

Represent facts as P(t,M,C,D) where:

M- fuzzy measure of P(t) holding

C – confidence as probability of at least P(t,M) holding

D – set of facts on which P(t,M,C) depends

Represent rules as

P1(t1,M1,C1,D1) & ... & Pn(tn,Mn,Cn,Dn) &

M1>L1 & ... & Mn>Ln & A1 .... & Am

->

P(t,M,f(M1,...,M2),g(C1,...,Cn,D1,...,Dn),union(D1,...,Dn))

Summary 2

Add evidence cumulating rule

Pred(X,M1,C1,D1) & Pred(X,M2,C2,D2) &
Empty(Intersection(D1,D2))
->
Pred(X,min(M1,M2),(C1+C2)-(C1*C2),union(D1,D2))

Add extended subsumption

Pred(X,M1,C1,D1) subsumes
Pred(Y,M2,C2,D2)
iff Y=Xs & M1>=M2 & C1>=C2 &
D1 is a subset of D2